

#### **IV. SHORELINE CHANGE RESULTS**

A shoreline change analysis was completed to assess shoreline advance and recession along the study area. The shoreline is typically defined as a specified elevation contour. For this study, the shoreline was defined as the +6.0 ft. NAVD88 contour, which represents the beach nourishment project design berm elevation (CPE-NC, 2015A). Shoreline change is calculated by comparing shoreline position along shore perpendicular transects or profiles. Typically, shoreline change is then annualized to describe recession and advance rates. Annualized shoreline change rates are calculated by dividing the shoreline change by the time period (number of years) between survey events (i.e. feet per year). These changes are described in terms of positive (“+”) or advance (shoreline moving seaward) and negative (“-”) or recession (shoreline moving landward).

The analysis discussed in this report for the Town of Duck evaluated the +6.0 ft. NAVD88 contour positions measured during the September 2013, December 2017, May 2019 and June 2020 beach profiles surveys. Even though the 2017 beach nourishment project was completed in June 2017, the December 2017 survey has been adopted to represent the post-construction conditions within the project area due to large-scale profile adjustments that normally occur immediately following the placement of beach fill. This and future annual monitoring reports will reference shoreline changes and volume changes in the project area relative to the December 2017 condition. This report also includes a shoreline comparison of what are referred to as baseline surveys, which represent the initial surveys conducted by CPE during the planning process for the projects. The first survey conducted along Duck by CPE, was conducted in September 2013. The September 2013 data were used as the existing condition in the design of the berm and dune design for the Town’s project. The last survey conducted prior to the 2017 beach nourishment operation by CPE was conducted in May 2015. The +6.0 ft. NAVD88 contour position for each survey was identified along shore perpendicular transects spaced at approximately 1,000-foot intervals at the profiles along the monitoring area identified in Table 1.

**Table 1. Profile Survey Baseline and Azimuth**

<b>Profile</b>	<b>Easting</b>	<b>Northing</b>	<b>Azimuth</b>
D-01	2951387.5	918267.7	70
D-02	2951733.8	917384.4	70
D-03	2952103.0	916429.4	70
D-04	2952464.0	915495.3	70
D-05	2952849.3	914598.0	70
D-06	2953224.4	913696.9	70
D-07	2953607.3	912798.8	70
D-08	2953983.0	911897.9	70
D-09	2954356.7	910994.8	70
D-10	2954759.1	910066.7	70
D-11	2955158.1	909133.1	70
D-12	2955461.4	908412.5	70
D-13	2955874.3	907478.4	70
D-14	2956252.1	906578.3	70
D-15	2956628.6	905677.8	70
D-16	2956978.7	904767.7	70
D-17	2957333.7	903863.9	70
D-18	2957718.8	902886.5	70
D-19	2957932.5	902331.0	70
D-20	2958139.7	901760.7	70
D-21	2958472.1	900958.7	70
D-22	2958754.0	900228.8	70
D-23	2958992.7	899515.6	70
D-24	2959267.2	898739.8	70
D-25	2959601.7	897824.3	70
D-26	2959928.6	896902.3	70
D-27	2960250.6	895981.9	70
D-28	2960604.1	895073.0	70
D-29	2960963.6	894166.2	70
D-30	2961317.7	893257.6	70
D-31	2961676.7	892350.7	70
D-32	2962078.1	891379.4	70
D-33	2962439.4	890553.2	70
D-34	2962839.6	889616.1	70

The changes in the position of the +6.0 ft. NAVD88 contour measured between the September 2013 baseline survey and June 2020 are provided in Table 2. Short-term measured changes of the +6.0 ft. NAVD88 contour that occurred between May 2019 and June 2020 are also provided in Table 2. These values represent actual changes and not rates.

Table 3 shows rates of change for the +6.0 ft. contour between September 2013 (baseline survey) and June 2020, December 2017 (Post-Construction) to June 2020, and May 2019 to June 2020. The September 2013 to June 2020 time period represents long-term rates since CPE began monitoring the Town's Shoreline. The Table also includes average shoreline changes measured from 1996 to 2011 using historic LiDAR data. These rates represent the rate of change of the MHW contour as opposed to the +6.0 ft. contour, however they allow for a comparison of historic rates with more current rates.

Figure 3 graphically displays the location of +6.0 ft. NAVD88 shorelines for the entire monitoring area relative to the September 2013 shoreline. The relative shorelines shown are for December 2017 (Post-Construction), May 2019, and June 2020. A review of Figure 3 shows the Project Area shoreline retreated landward between May 2019 and June 2020. This period includes the impacts of Hurricane Dorian on the project. During the same time period from May 2019 to June 2020 the shoreline 5,000 ft. north of the Project Area (stations D-05 and D-10) experienced positive shoreline change. South of the Project Area, between stations D-20 and D-25, the shoreline experienced negative shoreline change. In this regard, the characterization of shoreline changes within the monitoring areas is best represented by averaging shoreline trends for multiple profile lines within certain sections. As discussed below, average shoreline trends were computed for the three subareas within the monitoring area, namely, North of the Beach Project, the Project Area, and South of the Beach Project.

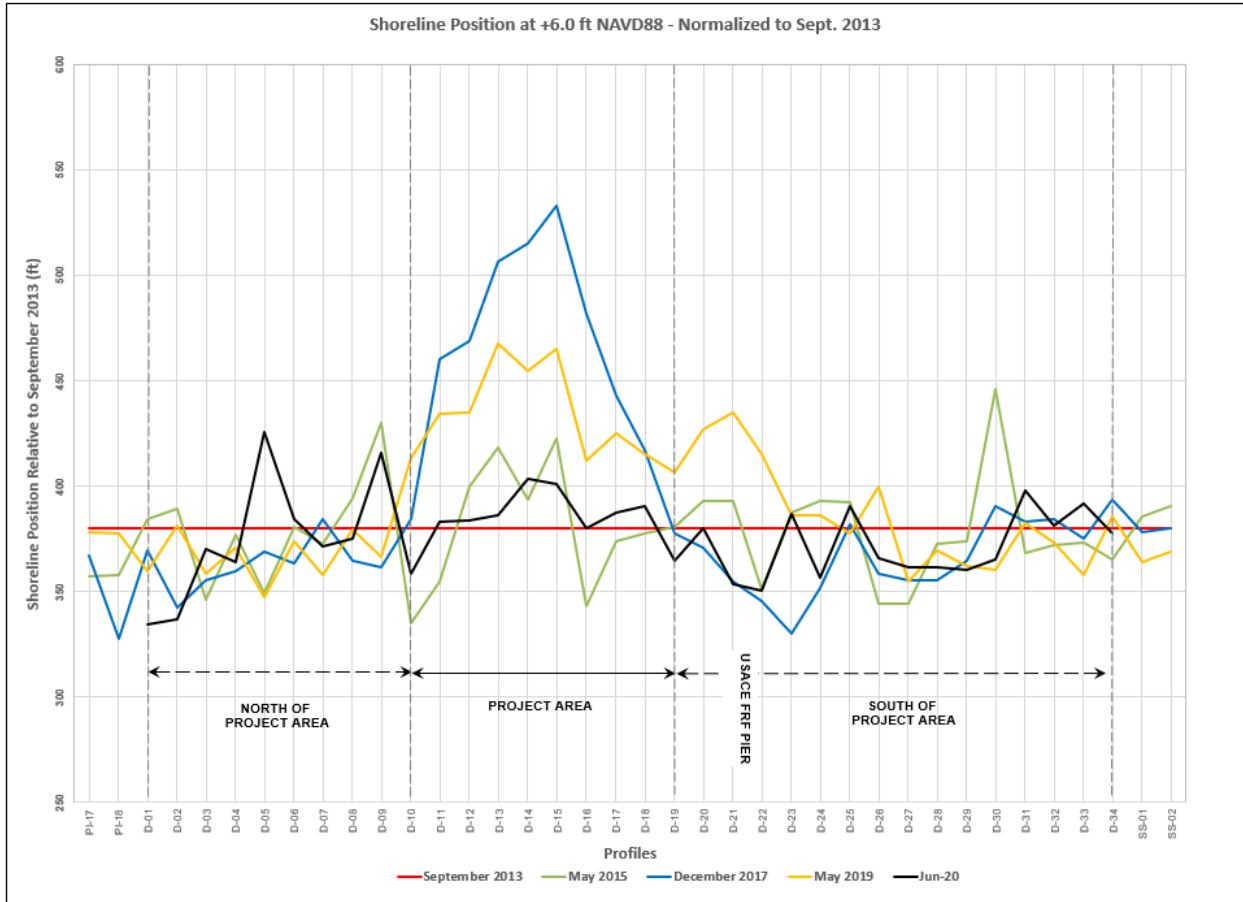
**Table 2. +6.0 FT NAVD88 Shoreline Changes (ft.)**

PROFILE		September 2013 (Baseline) to June 2020 (Year-3)	May 2019 (Year-2) to June 2020 (Year-3)
Area North of Project	D-01	-45.5	-25.3
	D-02	-43.1	-44.5
	D-03	-9.6	12.1
	D-04	-16.0	-6.5
	D-05	45.6	77.9
	D-06	4.3	10.3
	D-07	-8.5	13.5
	D-08	-5.0	-4.5
	D-09	35.8	49.2
Project Area	D-10	-21.2	-54.5
	D-11	3.3	-50.8
	D-12	3.7	-51.0
	D-13	6.4	-81.3
	D-14	23.2	-51.7
	D-15	21.1	-63.9
	D-16	0.3	-31.9
	D-17	7.4	-37.9
	D-18	10.6	-24.8
	D-19	-15.5	-42.0
Area South of Project	D-20	0.3	-46.6
	D-21	-26.2	-81.0
	D-22	-29.3	-64.2
	D-23	7.0	1.0
	D-24	-23.6	-30.0
	D-25	10.6	13.0
	D-26	-14.4	-34.0
	D-27	-18.6	6.4
	D-28	-18.2	-7.6
	D-29	-19.5	-1.9
	D-30	-14.8	4.8
	D-31	17.9	15.1
	D-32	1.6	8.6
	D-33	12.0	34.0
	D-34	-2.4	-8.0
<b>AREA NORTH OF PROJECT (D-01 TO D-10)</b>		-6.3	2.8
<b>PROJECT AREA (D-10 TO D-19)</b>		3.9	-49.0
<b>AREA SOUTH OF PROJECT (D-19 TO D-34)</b>		-8.3	-14.5

**Table 3. +6.0 FT NAVD88 Shoreline Change Rates (ft./yr.)**

PROFILE	MHW Shoreline Change from 1996 to 2011*	September 2013 (Baseline) to June 2020 (Year-3)	December 2017 (Post-Con) to June 2020 (Year-3)	May 2019 (Year-2) to June 2020 (Year-3)
Area North of Project	D-01	-6.7	-14.1	-23.4
	D-02	-6.4	-2.2	-41.1
	D-03	-1.4	6.1	11.2
	D-04	-2.4	1.7	-6.0
	D-05	6.8	22.7	71.9
	D-06	0.6	8.4	9.5
	D-07	-1.3	-5.2	12.4
	D-08	-0.7	4.1	-4.1
	D-09	5.3	21.8	45.4
Project Area	D-10	-3.1	-10.1	-50.3
	D-11	0.5	-30.8	-46.9
	D-12	0.6	-34.1	-47.1
	D-13	1.0	-47.9	-75.0
	D-14	3.4	-44.7	-47.7
	D-15	3.1	-52.7	-59.0
	D-16	0.0	-40.5	-29.5
	D-17	1.1	-22.3	-35.0
	D-18	1.6	-10.6	-22.9
	D-19	-2.3	-5.3	-38.8
Area South of Project	D-20	0.0	3.8	-43.1
	D-21	-3.9	-0.4	-74.7
	D-22	-4.3	2.2	-59.3
	D-23	1.0	22.7	0.9
	D-24	-3.5	2.0	-27.7
	D-25	1.6	3.4	12.0
	D-26	-2.1	2.9	-31.4
	D-27	-2.8	2.3	5.9
	D-28	-2.7	2.6	-7.0
	D-29	-2.9	-1.8	-1.7
	D-30	-2.2	-10.1	4.5
	D-31	2.7	5.9	13.9
	D-32	0.2	-1.2	7.9
	D-33	1.8	6.9	31.4
	D-34	-0.4	-6.3	-7.4
<b>AREA NORTH OF PROJECT</b> (D-01 TO D-10)	1.0	-0.9	3.3	2.6
<b>PROJECT AREA</b> (D-10 TO D-19)	-2.2	0.6	-29.9	-45.2
<b>AREA SOUTH OF PROJECT</b> (D-19 TO D-34)	-0.4	-1.2	1.9	-13.4

\* Average MHW shoreline change rates provided as a reference only.



**Figure 3. Historical +6.0 FT NAVD88 position relative to the September 2013 +6.0 FT NAVD88 position.**

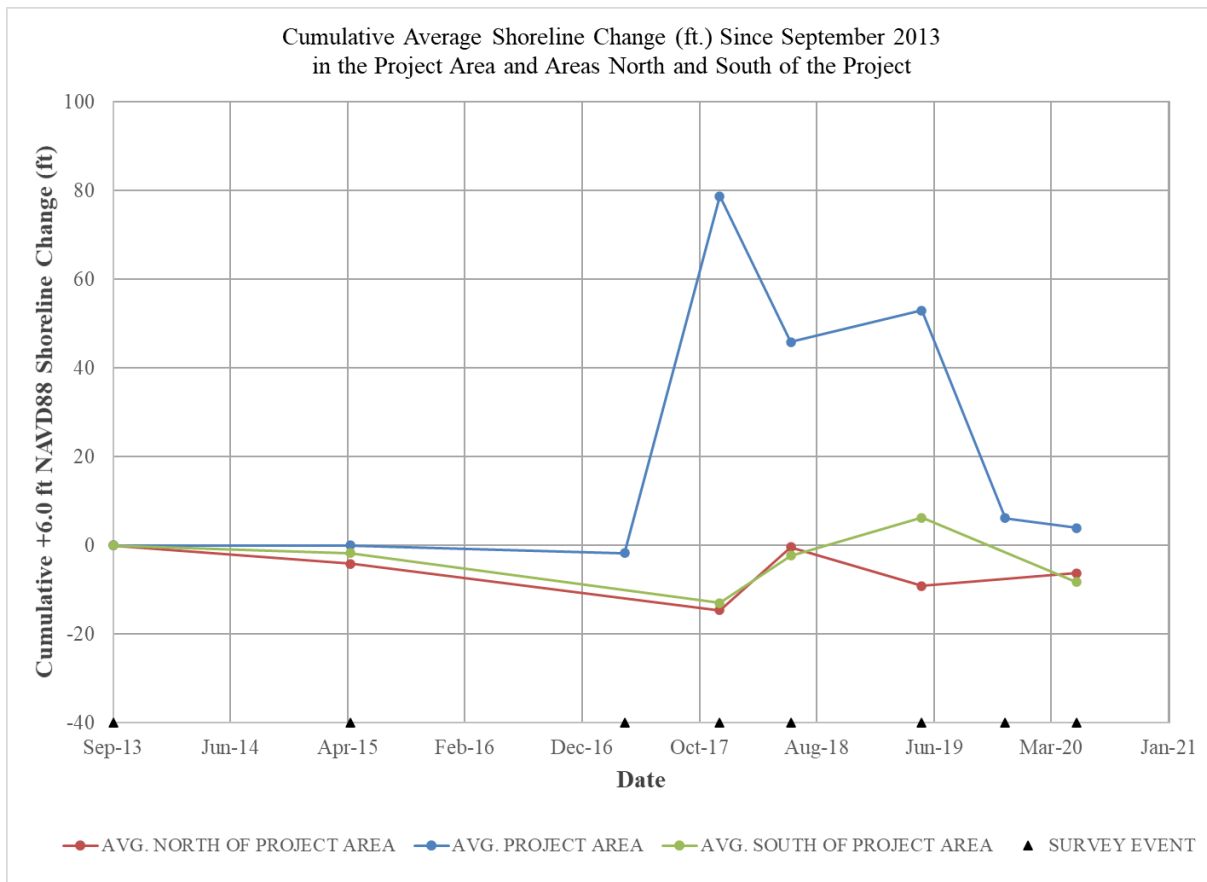
**Project Shoreline Changes**

**Project Area.** With the construction of the beach nourishment project in 2017, the +6 ft. NAVD88 contour was extended seaward +183 ft. based on comparisons of the before dredge (BD) and after dredge (AD) surveys. However, these numbers reflect the change based on the placement of the unequilibrated beach fill construction template. Between April 2017 and December 2017, the beach fill underwent immediate post-fill adjustments which reduced the initial advancement of the +6.0 ft. NAVD88 contour to an average of +89.5 feet. Note, this average does not include D-19 as this profile was not surveyed during the April 2017 pre-construction survey. The project average includes D-10 through D-18. This seaward advance of the +6.0 ft. NAVD88 contour is more reflective of the effective advance as a result of the project.

Beach profile data indicated that between December 2017 and June 2020, the average shoreline change of the +6 ft. NAVD88 contour within the project area was -74.8 feet, which is equivalent to a rate of change of 29.9 ft./yr. A profile-by-profile comparison shows a wide range of rates of change in the position of the +6.0 ft. NAVD88 contour (Table 3). The greatest shoreline changes measured appear to be taking place in the central portion of the project between Station D-13 (Sea Tern Dr.) and D-16 (Pintail Dr.). The average shoreline change along those 4 profiles was -116.2 ft. The average shoreline change between December 2017 and June 2020, in the northern portion of the project area from D-12 (Sound Sea Ave.) to D-10 (Skimmer Way) was -62.5 ft.; whereas, the average shoreline change in the southern part of the project

area from D-17 (located at the south end of Buffell Head Rd.) to D-19 (northern USACE FRF boundary) was -31.9 ft. Table 2 includes measured shoreline change for each profile as well as the average shoreline change for the beach nourishment project and the monitored areas outside the project. Table 3 includes rates of change of the +6.0 ft. NAVD88 contour for each profile as well as the average rate of change for the beach nourishment project and the monitored areas outside the project.

Figure 4 depicts the average cumulative change in the position of the +6.0 ft. NAVD88 contour within the project area (i.e. average change of stations D-10 to D-19) between September 2013 and June 2020. The large increase in the cumulative average shoreline change in the Project Area between May 2015 and December 2017 reflects the 89-foot seaward advancement of the average shoreline associated with the beach fill project completed in July 2017. After an initial shoreline recession measured between December 2017 and June 2018, the shoreline change appeared to stabilize somewhat and even advance seaward on average, between June 2018 and May 2019. Between May 2019 and June 2020, the average position of the +6.0 ft. NAVD88 contour moved -49.0 ft. (landward) along the project area. Note that the shoreline position measured in December 2019, during the Post-Dorian data collection, is also included in Figure 4 for the Project Area.



**Figure 4. Average cumulative changes in the +6.0 ft. NAVD88 contour position since September 2013 in the Project Area and in the areas north and south of the Project Area.**

## **Areas North and South of Project Area**

**Area North of Project.** The average shoreline change measured along the +6.0 ft. NAVD88 contour between September 2013 and June 2020, north of the beach nourishment project (stations D-01 to D-10), was -6.3 ft. (landward movement). This is equivalent to a rate of -0.9 ft./yr. when annualized over the 6.75-year period. As shown in Figure 4, between September 2013 and December 2017, the Area North of the Project experienced negative shoreline change. Between December 2017 and June 2018, the shoreline position experienced a positive change, and since that time, the +6.0 ft. NAVD88 contour has remained relatively stable on average.

As seen in Table 2, the individual measurements from profile to profile vary considerably. The shoreline change at station D-05 (S Station Bay Dr) has experienced the greatest positive change of +45.6 ft. whereas the greatest negative change of -45.5 ft. was measured at station D-01 (Station 1 Ln).

During the recent survey interval from May 2019 to June 2020, the average shoreline change was 2.8 feet. Although the average change was positive (seaward movement), the measured shoreline change varied throughout the area. In general, the northernmost profiles at stations D-01 and D-02 had an average shoreline change of -34.9 feet (landward). The average shoreline change measured from station D-03 to D-09 (south end of S. Baum Trail to Pelican Way) was +21.7 feet (seaward). Station D-10, located at Skimmer Way, which is considered the boundary between the Project Area and the Area North of Project, experienced the greatest negative (landward) shoreline change between May 2019 and June 2020 (-54.5 feet.)

**Area South of Project.** The average shoreline change of the +6.0 ft. NAVD88 contour south of the project area (stations D-19 to D-34) between September 2013 and June 2020 was -8.3 ft. (landward movement). This is equivalent to a rate of -1.2 ft./yr. when annualized. As shown in Figure 4, between September 2013 and December 2017, the Area South of the Project experienced negative shoreline change. Between December 2017 and May 2019, the area experienced an average positive shoreline change. However, between May 2019 and June 2020, the average shoreline change has been negative.

As seen in Table 2 and Table 3, the individual measurements from profile to profile vary considerably. The average shoreline change measured from D-19 (northern boundary of FRF property) and D-26 (Cook Dr.) between May 2019 and June 2020 was -35.5 feet. This includes profiles at stations D-21 and D-22, both of which fall within the FRF, which showed shoreline change of -81.0 feet and -64.2 feet, respectively. South of Cook Dr., between stations D-27 (Wampum Dr.) and the southern end of Town (D-34), the average shoreline change between May 2019 and June 2020 was +6.4 feet.